Quantitative and qualitative comparison of MR imaging of the temporomandibular joint at 1.5 and 3.0 T using an optimized high-resolution protocol

Manoliu, Andrei ; Spinner, Georg ; Wyss, Michael ; Erni, Stefan ; Ettlin, Dominik A ; Nanz, Daniel ; Ulbrich, Erika J ; Gallo, Luigi M ; Andreisek, Gustav

Abstract: OBJECTIVES: To quantitatively and qualitatively compare MRI of the temporomandibular joint (TMJ) using an optimized high-resolution protocol at 3.0 T and a clinical standard protocol at 1.5 T. METHODS: A phantom and 12 asymptomatic volunteers were MR imaged using a 2-channel surface coil (standard TMJ coil) at 1.5 and 3.0 T (Philips Achieva and Philips Ingenia, respectively; Philips Healthcare, Best, Netherlands). Imaging protocol consisted of coronal and oblique sagittal proton density-weighted turbo spin echo sequences. For quantitative evaluation, a spherical phantom was imaged. Signal-to-noise ratio (SNR) maps were calculated on a voxelwise basis. For qualitative evaluation, all volunteers underwent MRI of the TMJ with the jaw in closed position. Two readers independently assessed visibility and delineation of anatomical structures of the TMJ and overall image quality on a 5-point Likert scale. Quantitative and qualitative measurements were compared between field strengths. RESULTS: The quantitative analysis showed similar SNR for the high-resolution protocol at 3.0 T compared with the clinical protocol at 1.5 T. The qualitative analysis showed significantly better visibility and delineation of clinically relevant anatomical structures of the TMJ, including the TMJ disc and pterygoid muscle as well as better overall image quality at 3.0 T than at 1.5 T. CONCLUSIONS: The presented results indicate that expected gains in SNR at 3.0 T can be used to increase the spatial resolution when imaging the TMJ, which translates into increased visibility and delineation of anatomical structures of the TMJ. Therefore, imaging at 3.0 T should be preferred over 1.5 T for imaging the TMJ.

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RESEARCH ARTICLE

Quantitative and qualitative comparison of MR imaging of the temporomandibular joint at 1.5 and 3.0 T using an optimized high-resolution protocol

[1,2]Andrei Manoliu, [2]Georg Spinner, [2]Michael Wyss, [3]Stefan Erni, [3]Dominik A Ettlin, [1]Daniel Nanz, [1]Erika J Ulbrich, [3]Luigi M Gallo and [1]Gustav Andreisek

[1]Department of Radiology, Institute for Diagnostic and Interventional Radiology, University Hospital Zurich, University of Zurich, Zurich, Switzerland; [2]Institute for Biomedical Engineering, University of Zurich and ETH Zurich, Zurich, Switzerland; [3]Center of Dental Medicine of the University of Zurich, Zurich, Switzerland

Objectives: To quantitatively and qualitatively compare MRI of the temporomandibular joint (TMJ) using an optimized high-resolution protocol at 3.0 T and a clinical standard protocol at 1.5 T.
Methods: A phantom and 12 asymptomatic volunteers were MR imaged using a 2-channel surface coil (standard TMJ coil) at 1.5 and 3.0 T (Philips Achieva and Philips Ingenia, respectively; Philips Healthcare, Best, Netherlands). Imaging protocol consisted of coronal and oblique sagittal proton density-weighted turbo spin echo sequences. For quantitative evaluation, a spherical phantom was imaged. Signal-to-noise ratio (SNR) maps were calculated on a voxelwise basis. For qualitative evaluation, all volunteers underwent MRI of the TMJ with the jaw in closed position. Two readers independently assessed visibility and delineation of anatomical structures of the TMJ and overall image quality on a 5-point Likert scale. Quantitative and qualitative measurements were compared between field strengths.
Results: The quantitative analysis showed similar SNR for the high-resolution protocol at 3.0 T compared with the clinical protocol at 1.5 T. The qualitative analysis showed significantly better visibility and delineation of clinically relevant anatomical structures of the TMJ, including the TMJ disc and pterygoid muscle as well as better overall image quality at 3.0 T than at 1.5 T.
Conclusions: The presented results indicate that expected gains in SNR at 3.0 T can be used to increase the spatial resolution when imaging the TMJ, which translates into increased visibility and delineation of anatomical structures of the TMJ. Therefore, imaging at 3.0 T should be preferred over 1.5 T for imaging the TMJ.
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Keywords: temporomandibular joint; temporomandibular joint disc; temporomandibular joint disorders; magnetic resonance imaging (MRI); signal-to-noise ratio (SNR)

Introduction

Temporomandibular disorders (TMDs) are a collective term for various pathologies of the temporomandibular joint (TMJ) characterized by mutual features, such as pain, clicking or crepitus of the TMJ and alterations of the mouth opening path.[1,2] With a prevalence of 12% in the adult population,[3] TMDs are the most common cause for orofacial pain of non-dental origin.[4] TMDs have a great impact on the quality of life of patients and

Correspondence to: Andrei Manoliu. E-mail: andrei.manoliu@usz.ch
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are related to a wide diversity of frequent disorders, including tension and migraine headache, depression, fatigue, sleep apnoea, obesity and Type 2 diabetes mellitus.[5,6] In addition, TMDs cause great socioeconomic costs, causing 17,800,000 lost workdays for every 100,000,000 working adults per year in the USA.[3,7] While the need for early detection of the pathological processes underlying TMD is evident, the diagnostic process is still subject of substantial discussion.[8]

In cases where imaging is required, MRI has been considered the imaging method of choice over the last decade to evaluate key features of TMD, such as temporomandibular disc displacement or alterations of cartilage and bones.[9,10] Currently, MRI of the TMJ is mainly performed at 1.5 T using dedicated surface coils.[11] Since the signal intensity [or, in particular, the signal-to-noise ratio (SNR)] is assumed to scale linearly with the field strength, theoretical considerations suggest that imaging the TMJ at higher field strengths such as 3.0 T should allow considerably higher spatial resolutions at comparable scan durations and therefore enable superior visibility of TMJ's anatomical key structures.[12]

Although theoretical considerations suggest great advantages for MRI of the TMJ at higher magnetic field strengths, evidence in the literature for the use of 3.0 T is still scarce and only few studies[13,14] investigated the benefit of imaging the TMJ at 3.0 T compared with 1.5 T. Stehling et al[13] showed a better visibility of some anatomical structures, and Schmid-Schwap et al[14] found a better diagnostic accuracy in patients with anterior disc displacement. However, these early studies had several limitations and only used commercially non-available custom-made bilateral phased-array surface coils or applied imaging protocols, which have not been optimized for imaging the TMJ at 3.0 T.[13,14] In addition, the two aforementioned studies focused on qualitative assessment only, whereas the SNR and its potential impact on imaging results have not been quantitatively assessed so far. Therefore, clear evidence for a superior quantitative and qualitative performance of imaging the TMJ at 3.0 T using commercially available coils and easily reproducible dedicated imaging protocols is still missing and needs to be addressed.

The aim of the present study was to quantitatively and qualitatively compare an optimized high-resolution protocol at 3.0 T and a clinical standard protocol at 1.5 T for imaging the TMJ using a commercially available two-channel surface coil.

Methods and materials

This was a prospective institutional review board-approved MRI study. It included imaging of a phantom and a cohort of asymptomatic healthy volunteers. All volunteers gave written informed consent. The study was registered in the official research database of the University of Zurich.

Phantom imaging

The first part of the study included standardized SNR measurements for which a "Braino" phantom (GE Medical Systems, Milwaukee, WI) containing 12.5 mM of *N*-acetyl-L-aspartic acid (NAA), 10 mM of creatine hydrate (Cr), 3 mM of choline chloride (Ch), 7.5 mM of *myo*-inositol (mI), 12.5 mM of L-glutamic acid (Glu), 5 mM of DL-lactic acid (Lac), sodium azide (0.1%), 50 mM of potassium phosphate monobasic (KH_2PO_4), 56 mM of sodium hydroxide (NaOH) and $1\ ml\ l^{-1}$ of Gd-DPTA (Magnevist®; Bayer Healthcare Germany, Leverkusen, Germany) was used. The phantom was a model for the head of a human subject and was placed accordingly on the scanner's patient table (Figure 1).

Volunteer imaging

For the second part of the study, 12 asymptomatic healthy volunteers (six females; mean age, 23.16 years; age range, 19–26 years; and six males; mean age, 25.33 years; age range, 20–29 years) who met the following inclusion criteria were included consecutively: age between 18 and 40 years and no past or current TMD. Exclusion criteria were pregnancy, metallic implants (including retainer) or any other contraindications for MRI (*e.g.* claustrophobia), as well as pain or functional symptoms in the area of the TMJ.

All volunteers underwent simultaneous bilateral MRI of their TMJs with the jaw in closed position using the two-channel SENSE Flex S coils (Philips Healthcare, Best, Netherlands) of both scanners (Figure 2). All subjects were positioned in the supine and head-first position. Scans were performed consecutively. To avoid potential imaging bias, half of the volunteers were first assessed at 1.5 T and the other half were assessed at 3.0 T first. The assignment was made randomly. One of the investigators (blinded, AM) was present at all imaging sessions to ensure the correct positioning of the human subjects and coils. Both TMJs were imaged at the same time.

MRI

MRI was performed on a clinical 1.5-T Philips Achieva system and a clinical 3.0-T Philips Ingenia system (Philips Healthcare) using standard commercially available two-channel surface coils (SENSE Flex S; Philips Healthcare). The phantom and human subjects were imaged using the same hardware and software as well as the same imaging set-up.

In general, sequences from the clinical standard protocol were applied. This included proton density-weighted turbo spin echo (PDw-TSE) MR sequences in oblique sagittal plane (field of view) positioned perpendicular to the mandibular condyle's transverse axis as well as a PDw-TSE MR sequence in coronal plane. For imaging at 1.5 T, sequence parameters applied in clinical routine were used (Table 1). For imaging at 3.0 T, the PDw-TSE sequences were optimized by improving the in-plane resolution of the images (Table 1). Care was taken to keep the acquisition time similar and to not extend the scan duration. This study design was chosen to reflect the clinical situation where 3.0-T protocols are typically different from 1.5 T to take advantage of the higher field strength.

To allow standardized SNR measurements in the phantom part of the study, the clinical sequence was accompanied by an additional identical scan without radiofrequency excitation and without gradient switching.

Image analysis

Quantitative signal-to-noise ratio measurements in the phantom: According to a previously described method[12] and strictly following a recently presented analysis algorithm,[15] the SNR was examined on a voxelwise basis employing a so-called noise scan, which is basically an additional sequence where the radiofrequency excitation and gradients are switched off by applying the following equation using dedicated in-house software routines (MATLAB®; MathWorks®, Natick, MA):

$$SNR = \frac{|\rho|}{\sigma} \approx \sqrt{d^H \psi^{-1} d}$$

where ρ is the exact magnitude of the available transverse magnetization for each voxel according to Roemer et al,[16] σ is the standard deviation of its corresponding noise components as described by Pruessmann et al,[17] d represents the complex values that a given pixel exhibits in each single-channel image, H denotes the complex conjugate transpose and ψ denotes the noise covariance matrix calculated from the noise scans as previously described.[12,17] Therefore, the applied software routine accounted for possible noise correlations among all coil channels. Subsequently, the phantom was manually segmented by one author (GS), and SNR values were extracted, resulting in one SNR value for each field strength.

Qualitative image evaluation in human subjects: All images were transferred to the University Hospital of Zurich's picture archiving and communication system (IMPAX® 6.0; Agfa Healthcare, Mortsel, Belgium) and independently evaluated by two fellowship-trained radiologists (GA and AM; 14 and 4 years' experience, respectively, with MRI of the musculoskeletal system). Both readers were blinded with regard to the subject's details as well as field strength. In accordance to a previously reported grading system,[13] images were evaluated in a random order for the overall image quality as well as the visibility and delineation of clinically relevant structures, *i.e.* the (a) TMJ disc (anterior band, intermediate zone, posterior band), (b) the bilaminar zone, (c) the mandibular fossa, (d) the mandibular condyle and (e) the pterygoid muscle on a 5-point Likert scale from 1 to 5 [1, excellent visibility; 2, good visibility; 3, moderate visibility; 4, poor visibility; and 5, not visible (complete lack of diagnostic information)].

Statistical analyses

Two-sample t-tests were used to evaluate potential SNR differences between the images assessed in the phantom at 1.5 and 3.0 T. Kappa statistics were used to determine the interreader agreement in the qualitative MR image analysis of human subjects. According to Landis and Koch,[18] kappa values of 0.41–0.60 were considered as moderate agreement, values of 0.61–0.80 were considered as substantial agreement, values of 0.81–0.99 were considered as almost perfect agreement and values of 1.00 were considered as perfect agreement. To investigate statistically significant between-group differences regarding the visibility and delineation of clinically relevant anatomical structures as well as regarding the overall image quality using different field strengths, Wilcoxon signed-rank tests were performed [α-level of 0.05, corrected for multiple comparisons ($n = 13$)]. SPSS® software v. 22.0 (IBM Corporation, Armonk, NY; formerly SPSS Inc., Chicago, IL) was used for all statistical analyses.

Results

Quantitative signal-to-noise ratio data from phantom imaging

Quantitative analysis revealed similar SNR for the optimized protocol at 3.0 T compared with the clinical standard protocol at 1.5 T without statistically significant differences: mean ± standard deviation: 1.5 T, 60.42 ± 9.28; 3.0 T, 56.48 ± 7.62; $t = 1.604$; $p = 0.116$ (Figure 1).

Qualitative data from volunteer imaging

24 TMJ image sets of 12 healthy volunteers were evaluated. Interrater reliability ranged from "substantial agreement" to "almost perfect agreement" (Cohen's kappa: 1.5 T, 0.647–0.934; 3.0 T, 0.739–0.932) for the different anatomical structures (Table 2).

For both readers, qualitative analysis demonstrated significantly better overall image quality at 3.0 T than at 1.5 T (Wilcoxon signed-rank test: Reader 1, $p = 0.002$; Reader 2, $p = 0.001$). Furthermore, imaging at 3.0 T yielded significantly better visibility and delineation of the anterioposterior band of the temporomandibular disc as well as better visibility and delineation of the pterygoid muscle for both readers (Wilcoxon signed-rank tests, $p <$ 0.05, corrected for multiple comparisons, Table 3 and Figure 2). In addition, imaging at 3.0 T yielded better visibility of the intermediate zone of the temporomandibular disc and better visibility of the bilaminar zone; however, statistical significance did not survive correction for multiple comparisons (Table 3).

Discussion

To the best of our knowledge, the present study demonstrated for the first time that imaging the TMJ at 3.0 T at high resolution yielded better quantitative and qualitative performance than at 1.5 T when using commercially available TMJ surface coils. Despite higher resolution at 3.0 T, SNR was similar, with both magnetic field strengths, suggesting that gains in SNR due to a higher magnetic field

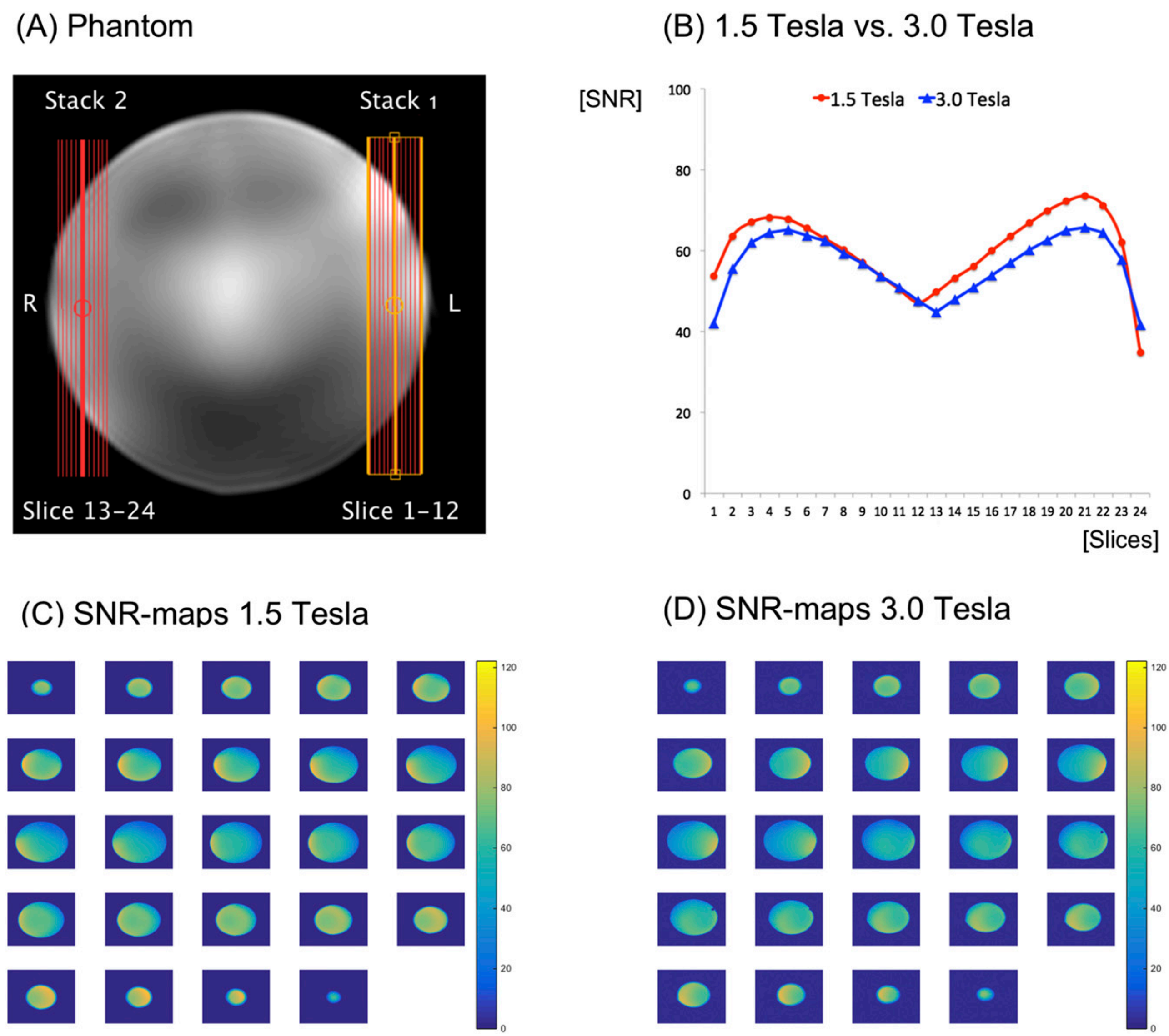

Figure 1 Quantitative analysis. Panel (a) shows the spherical phantom. Two stacks consisting of 12 slices each were imaged in sagittal orientation resulting in 24 slices numbered consecutively from left to right. Panel (b) shows a diagram displaying the signal-to-noise ratio (SNR) for both 1.5 and 3.0 T in the spherical phantom. The x-axis represents the number of slices and the y-axis represents the SNR. Values for 1.5 T are given in red and values for the 3.0 T are given in blue. For each slice, the mean SNR is given for both field strengths. Panels (c) and (d) show the voxelwise distribution of SNR for each slice, respectively, whereas panel (c) represents 1.5 T and panel (d) 3.0 T. In both panels (c, d), SNR values are colour-coded from 0 (blue) to 120 (yellow). For colour image see online.

strength can be used to increase spatial resolution while maintaining a robust SNR.

Quantitative analysis

To the best of our knowledge, no study so far has investigated the SNR at different field strengths for imaging the TMJ. In the present study, we applied an intricate voxelwise approach to calculate SNR for different field strengths in a phantom.[15] This approach yielded a comprehensive assessment of the spatial distribution of the SNR (Figure 1) with respect to the desired regions of assessment. Furthermore, our method yielded SNR maps for the whole field of view and correctly accounted for possible noise correlations among all coil channels. Applying this method, we found that SNR was similar for the high-resolution protocol at 3.0 T and the clinical standard protocol at 1.5 T. This result is well in line with the fact that measured SNR is not only related to the magnetic field strength but also to the voxel size.[12] In particular, SNR is negatively correlated with the spatial resolution; a higher spatial resolution (*i.e.* a smaller voxel size) is assumed to lower the SNR. In the present study, the gain in SNR due to the increased field strength at 3.0 T was used to increase the spatial resolution, yielding statistically similar SNR maps for both field strengths while the spatial resolution at 3.0 T was considerably higher

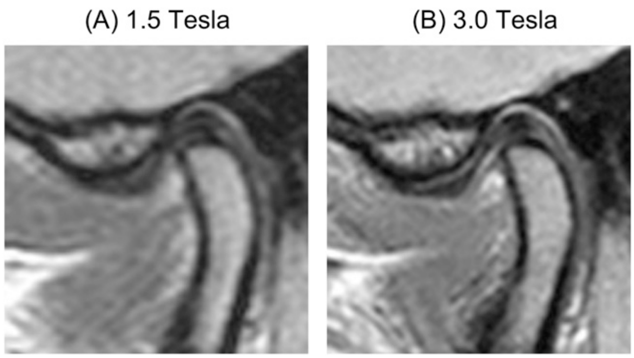

Figure 2 Qualitative analysis. proton density-weighted turbo spin echo oblique sagittal images in closed-mouth position at 3.0 T. Panels (a) and (b) show the images of a temporomandibular joint (TMJ) of an asymptomatic volunteer assessed at 1.5 T [panel (a), "good" overall image quality] and 3.0 T [panel (b), "excellent" image quality] using a dedicated, commercially available TMJ surface coil (FlexS; Philips Healthcare). In general, the overall image quality was significantly better on images obtained at 3.0 T. In particular, the visibility and delineation of the anterior band and the posterior band is increased at 3.0 T. See Table 3 for detailed presentation of between-group differences regarding visibility and delineation of all anatomical structures of the TMJ.

than at 1.5 T. Particularly when considering that in many cases the correlation between reported clinical symptoms and MRI findings in patients with TMDs is still unsatisfying,[19] exploiting SNR gains at higher field strengths to increase the spatial resolution should be desirable from a clinical perspective, since a better and more detailed depiction of the TMJ's anatomical subregions is assumed to improve diagnostic sensitivity when evaluating potential pathologies underlying TMDs.

Qualitative analysis

Using a high-resolution protocol, imaging the TMJ at 3.0 T yielded better visibility and delineation for several key structures of the TMJ, including the temporomandibular disc and the pterygoid muscle. Furthermore, overall image quality was higher at 3.0 T than at 1.5 T. Statistical differences remained significant after correction for multiple comparisons. It is to note, however, that the depiction of the temporomandibular fossa and condyle did not benefit from increased field strength, which is however clinically less important, since they can be already well depicted at 1.5 T.

These findings are in line with previous preliminary studies,[13,14] reporting better visibility of the temporomandibular disc at 3.0 T than at 1.5 T. In particular, Stehling et al[13] reported increased visibility of the temporomandibular disc in asymptomatic volunteers when imaged at 3.0 T compared with 1.5 T. However, a dedicated custom-made phased-array surface coil was used for imaging at 3.0 T, whereas a commercially available surface coil was used at 1.5 T. In another study, Schmidt-Schwap et al[14] found that imaging the TMJ at 3.0 T yielded better visibility of the position and shape of the disc and therefore provides increased diagnostic accuracy compared with 1.5 T in patients with suspected anterior disc displacement. However, the sequence parameters at both field strengths were kept almost identical, thus not exploiting potential benefits of higher magnetic field strengths, such as increased spatial resolution. Furthermore, both studies[13,14] focused on the temporomandibular disc and condyle only, neglecting other anatomical structures of high relevance regarding TMDs, such as the pterygoid muscle.

Therefore, our findings extend the current knowledge as follows. (a) In addition to better visibility and delineation of the temporomandibular disc, we found better visibility and delineation of the pterygoid muscle, particularly the part near the condylar insertion. These findings are of essential clinical interest, since the pathophysiology of TMDs is highly complex and can only be accurately assessed when evaluating the complete musculoskeletal functional unit of the TMJ, including the masticatory muscles. (b) In contrast to previous studies,[13] only commercially available coils (FlexS; Philips Healthcare) were used for imaging at both field strengths, ensuring that the reported results are not explained by different array designs. Moreover, the current results can be translated directly into a clinical setting, since the used

Table 1 Scan parameters of the PDw sequences at 1.5 and 3.0 T

	PDw-TSE sagittal		*PDw-TSE coronal*	
Parameter	*1.5 T*	*3.0 T*	*1.5 T*	*3.0 T*
FoV (mm)	150 × 150	150 × 150	120 × 180	120 × 180
Pixel size (mm)	0.60 × 0.75	0.50 × 0.50	0.60 × 0.75	0.50 × 0.50
Reconstructed pixel size (mm)	0.375 × 0.375	0.250 × 0.250	0.375 × 0.375	0.250 × 0.250
Slice thickness (mm)	2	2	2	2
Number of slices	2 × 12	2 × 12	24	24
TR	2000	2700	2000	2700
TE	30	26	30	26
Wfs in pixel (mm)	0.937	1.199	0.99	1.188
Effective wfs in image (mm)	0.6	0.6	0.6	0.6
Wfs (Hz)	231	362	217	365
TSE factor	7	7	8	7
ES	7.5	7.4	8	7.4
NSA	2	1	2	1
Scan time (min)	03 : 48	03 : 52	4 : 04	4 : 35

ES, echo spacing; FoV, field of view; NSA, number of signal averages; PDw-TSE, proton density-weighted turbo spin echo; TE, echo time; TR, repetition time; TSE, turbo spin echo; wfs, water-fat shift.

Table 2 Visibility and delineation of different anatomical structures of the temporomandibular joint at 1.5 and 3.0 T

	1.5 T						*3.0 T*					
	Reader 1		*Reader 2*		*Interrater reliability*		*Reader 1*		*Reader 2*		*Interrater reliability*	
Anatomical structure	*Mean*	*SD*	*Mean*	*SD*	*Kappa*	*p-value*	*Mean*	*SD*	*Mean*	*SD*	*Kappa*	*p-value*
Disc												
Visibility anterior band	2.75	0.53	2.79	0.58	0.91	<0.001	2.00	0.65	2.04	0.69	0.92	<0.001
Visibility intermediate zone	2.75	0.67	2.79	0.65	0.78	<0.001	2.12	0.79	2.20	0.77	0.87	<0.001
Visibility posterior band	2.83	0.63	2.87	0.61	0.77	<0.001	2.12	0.79	2.12	0.79	0.87	<0.001
Delineation	2.37	0.49	2.33	0.48	0.72	<0.001	2.20	0.72	2.25	0.67	0.93	<0.001
Bilaminar zone												
Visibility	2.79	0.65	2.75	0.60	0.92	<0.001	2.30	0.82	2.30	0.82	0.86	<0.001
Delineation	2.70	0.62	2.70	0.55	0.84	<0.001	2.39	1.07	2.47	1.08	0.88	<0.001
Mandibular fossa												
Visibility	2.25	0.60	2.20	0.58	0.76	<0.001	2.04	0.62	2.04	0.55	0.83	<0.001
Delineation	2.25	0.44	2.29	0.46	0.89	<0.001	2.00	0.59	2.04	0.55	0.73	<0.001
Mandibular condyle												
Visibility	2.20	0.65	2.12	0.74	0.86	<0.001	2.04	0.69	2.00	0.65	0.78	<0.001
Delineation	2.41	0.77	2.45	0.77	0.93	<0.001	2.16	0.70	2.08	0.65	0.86	<0.001
Pterygoid muscle												
Visibility	2.75	0.44	2.79	0.41	0.64	0.001	1.87	0.74	1.87	0.68	0.85	<0.001
Delineation	2.41	0.50	2.45	0.50	0.74	<0.001	1.83	0.48	1.91	0.58	0.81	<0.001
Overall image quality	2.62	0.49	2.58	0.50	0.73	<0.001	1.95	0.55	1.91	0.50	0.90	<0.001

SD, standard deviation.
Mean and SD are given for each structure. Grading was based on Likert scales ranging from 1 (excellent visibility) to 5 (not visible). For interrater reliability, kappa values and corresponding p-values are given.

surface coils are widely available. (c) Furthermore, the imaging protocol applied in the present study was specifically optimized to increase the visibility of all relevant structures of the TMJ at 3.0 T. In particular, the gains in SNR due to the higher magnetic field strength were used to increase the spatial resolution, yielding an additional improvement of the visibility of anatomical structures when compared with previous reported findings.[13] (d) To the best of our knowledge, the present study was the first to underpin the aforementioned results by assessing and evaluating the SNR obtained with different sequences and field strengths to ensure a systematic reliability of the reported results.

Table 3 Between-group differences of visibility and delineation of anatomical structures of the temporomandibular joint at 1.5 and 3.0 T

	1.5 T compared with 3.0 T			
	Reader 1		*Reader 2*	
Anatomical structure	*Z-value*	*p-value*	*Z-value*	*p-value*
Disc				
Visibility anterior band	−3.10	*0.002*	−3.21	*0.001*
Visibility intermediate zone	−2.74	0.006	−2.63	0.008
Visibility posterior band	−3.54	*0.000*	−3.26	*0.001*
Delineation	−0.96	0.334	−0.53	0.593
Bilaminar zone				
Visibility	−2.20	0.027	−2.13	0.033
Delineation	−1.19	0.232	−0.97	0.332
Mandibular fossa				
Visibility	−1.14	0.251	−0.94	0.346
Delineation	−1.42	0.153	−1.51	0.130
Mandibular condyle				
Visibility	−1.00	0.317	−0.77	0.439
Delineation	−0.92	0.357	−1.56	0.118
Pterygoid muscle				
Visibility	−3.50	*<0.001*	−3.57	*<0.001*
Delineation	−3.11	*0.002*	−2.96	*0.003*
Overall image quality	−3.11	*0.002*	−3.23	*0.001*

Wilcoxon signed-rank tests were performed for each structure. Z-values and corresponding p-values are given for each reader. Values in italics indicate that tests remained significant after correction for multiple comparisons (n = 13).

Limitations

Several limitations have to be acknowledged. First, the sample size was small. The present study included only 12 asymptomatic healthy volunteers. However, the size of the present study group is in line with a previously published study.[13] Second, only asymptomatic healthy volunteers were included. Although it is expected that the main findings of the present study may apply to patients as well, it has to be taken into consideration that TMDs are very heterogeneous, reaching from subtle soft-tissue lesions to clearly visible dislocations. Since the present study did not investigate the possible impact of the presented approach on the sensitivity and specificity of the MR-based diagnostic process in patients with TMDs, further studies are necessary to evaluate potential benefits of imaging the TMJ at 3.0 T with respect to various pathologies underlying TMDs. Third, MRI of the TMJ is frequently performed in closed- as well as in open-mouth position, increasing the diagnostic accuracy regarding displacement of the disc, whereas in the present study, imaging was performed in closed-mouth position only. However, since all assessed structures are perfectly visible in closed-mouth position, we suppose that the acquired images are sufficient to infer on potential benefits of imaging the TMJ at higher field strengths. Fourth, qualitative assessment of obtained MR images was performed only once by each reader without evaluating the intrareader agreement. However, interreader agreement between the two readers ranged from "substantial agreement" to "almost perfect agreement" for both field strengths, suggesting robust and reliable reproducibility regarding the evaluated data sets. Fifth, there was lack of a gold standard. However, Sanal et al[20] demonstrated recently that MRI of cadaveric TMJs at 3.0 T provides an excellent characterization of the TMJ's anatomy, suggesting that MRI of the TMJ might represent an excellent surrogate for anatomical structures when performed in study volunteers.

Clinical implications

The present study indicated that imaging the TMJ at 3.0 T yields a great potential for the clinical routine. First, imaging at 3.0 T allowed not only for a better evaluation of the temporomandibular disc but also of the masticatory muscles, likely facilitating an improved evaluation of the masticatory system in general. Second, 3.0-T MR scanners are broadly available at most MR sites. Thus, the expansion of the technique could soon accelerate. Finally, the presented optimized MR protocol and imaging set-up can easily be translated into clinical settings, since only commercially available equipment was used. Taken together, the present study presented an approach, which can easily be translated into clinical settings, thus potentially improving the diagnostic accuracy regarding possible pathologies underlying TMD.

Conclusions

Imaging the TMJ at 3.0 T yielded significantly better image quality as well as visibility and delineation of clinically relevant anatomical structures than at 1.5 T using a commercially available two-channel surface coil and might therefore be preferred in clinical routine.

Conflict of interest

This was a prospective institutional review board-approved MRI study. It included imaging of a phantom and a cohort of asymptomatic healthy volunteers. All volunteers gave written informed consent.

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